

WHAT IS CLAIMED IS:

1. A non-linear characteristic reproducing apparatus wherein upon receipt of a predetermined first state quantity, a non-linear transformation processing is applied to the entered first state quantity so that a second state quantity is generated and outputted, said non-linear characteristic reproducing apparatus comprising:

a state quantity transformation unit for linear-transforming the first state quantity to the second state quantity every sampling time in accordance with a transformation parameter set up; and

a non-linear characteristic reproducing unit for determining a transformation parameter for transformation at a subsequent sampling time in accordance with an estimated observation quantity at the subsequent sampling time of at least one state quantity of the first state quantity and the second state quantity or a state quantity derived from said one state quantity to set the determined transformation parameter to said state quantity transformation unit.

2. A non-linear characteristic reproducing apparatus according to claim 1, wherein said non-linear characteristic reproducing unit receives the estimated observation quantity and one or more variables as well, and determines the transformation parameter in accordance with

the estimated observation quantity and one or more variables thus received.

3. A non-linear characteristic reproducing apparatus according to claim 1, wherein said non-linear characteristic reproducing unit determines in form of the transformation parameter a normalized estimation value in which an estimation value of the second state quantity at the subsequent sampling time is normalized with the estimated observation quantity.

4. A non-linear characteristic reproducing apparatus according to claim 3, wherein said non-linear characteristic reproducing unit the estimation value of the second state quantity at the subsequent sampling time is divided or differentiated with an absolute value of the estimated observation quantity, so that the estimated observation quantity is determined in form of the transformation parameter.

5. A non-linear characteristic reproducing apparatus according to claim 1, wherein said non-linear characteristic reproducing apparatus is an apparatus for reproducing characteristics of a non-linear spring, said state quantity transformation unit performs a transformation between a velocity difference on both ends of the non-linear spring and a variation of load of the

non-linear spring, and

said non-linear characteristic reproducing unit determines a transformation parameter for performing transformation between the velocity difference on both ends of the non-linear spring as an object of a characteristic reproduction and the variation of load of the non-linear spring at a subsequent sampling time in accordance with an estimated observation quantity at the subsequent sampling time of the velocity difference on both ends of the non-linear spring to set the determined transformation parameter to said state quantity transformation unit.

6. A non-linear characteristic reproducing apparatus according to claim 1, wherein said non-linear characteristic reproducing apparatus is an apparatus for reproducing characteristics of an air spring,

said state quantity transformation unit performs a transformation between a deformation velocity of the air spring and a variation of an internal pressure of the air spring, and

said non-linear characteristic reproducing unit determines a transformation parameter for performing transformation between the deformation velocity of the air spring as an object of a characteristic reproduction and the variation of the internal pressure of the air spring at a subsequent sampling time in accordance with an estimated observation quantity at the subsequent sampling time of the

deformation velocity of the air spring to set the determined transformation parameter to said state quantity transformation unit.

5           7. A non-linear characteristic reproducing apparatus according to claim 1, wherein said non-linear characteristic reproducing apparatus is an apparatus for reproducing characteristics of a link mechanism,

10           said state quantity transformation unit transforms a value of velocity or angular velocity of a supporting point portion of the link mechanism, and

15           said non-linear characteristic reproducing unit determines a transformation parameter for transforming the value of velocity or angular velocity of the supporting point portion of the link mechanism as an object of a characteristic reproduction at a subsequent sampling time in accordance with an estimated observation quantity at the subsequent sampling time of velocity or angular velocity applied to the supporting point portion of the link  
20 mechanism to set the determined transformation parameter to said state quantity transformation unit.

25           8. A non-linear characteristic reproducing apparatus according to claim 7, wherein said state quantity transformation unit transforms a value of velocity or angular velocity of the supporting point portion of the link mechanism, and also a value of force or torque applied

to the supporting point portion, using the same parameter as that used for transformation of the value of velocity or angular velocity of the supporting point portion of the link mechanism, said parameter being set by said non-linear characteristic reproducing unit.

9. A non-linear characteristic reproducing apparatus according to claim 1, wherein said non-linear characteristic reproducing apparatus is an apparatus for reproducing characteristics of an object moving while involving a friction,

said state quantity transformation unit performs a transformation between a force applied to the object and a moving velocity of the object, and

said non-linear characteristic reproducing unit determines a transformation parameter for performing transformation between the force applied to the object as an object of a characteristic reproduction and the moving velocity of the object at a subsequent sampling time in accordance with an estimated observation quantity at the subsequent sampling time of the moving velocity of the object to set the determined transformation parameter to said state quantity transformation unit.

10. A non-linear characteristic reproducing apparatus according to claim 9, wherein said non-linear characteristic reproducing unit determines a frictional

force applied to the object in form of the transformation parameter to set the determined transformation parameter to said state quantity transformation unit, and

said state quantity transformation unit performs a transformation between the force applied to the object and the moving velocity of the object, in a case where a force, in which the frictional force set by said state quantity transformation unit is subtracted from the force applied to the object, is applied to an object in which an effect of the frictional force is neglected.

11. A non-linear characteristic reproducing apparatus according to claim 10, wherein said non-linear characteristic transformation unit comprises: a kinetic friction generating unit for determining a kinetic frictional force applied to the object as an object of a characteristic reproduction at a subsequent sampling time in accordance with an estimated observation quantity at the subsequent sampling time of the moving velocity of the object; a static friction generating unit for determining a static frictional force applied to the object as an object of a characteristic reproduction at a subsequent sampling time in accordance with an estimated observation quantity at the subsequent sampling time of the force applied to the object; and a frictional force selection unit for selecting one frictional force between the kinetic frictional force generated in said kinetic friction generating unit and the

static frictional force generated in said static friction  
generating unit in accordance with the estimated  
observation quantity at the subsequent sampling time of the  
moving velocity of the object to set the selected  
5 frictional force to said state quantity transformation unit.

12. A non-linear characteristic reproducing  
apparatus according to claim 11, wherein said kinetic  
friction generating unit determines a kinetic frictional  
10 force different in value in accordance with an estimated  
observation quantity at the subsequent sampling time of the  
moving velocity of the object.

13. A non-linear characteristic reproducing  
15 apparatus according to claim 1, wherein said non-linear  
characteristic reproducing apparatus is an apparatus for  
reproducing characteristics of a variable inertia moment  
mechanism in which an inertia moment is varied in  
accordance with an angular velocity,

20 said state quantity transformation unit performs a  
transformation between a torque applied to the variable  
inertia moment mechanism and an angular velocity of the  
variable inertia moment mechanism, and

said non-linear characteristic reproducing unit  
25 determines a transformation parameter for performing  
transformation between the torque applied to the variable  
inertia moment mechanism as an object of a characteristic

reproduction and an angular acceleration velocity of the variable inertia moment mechanism at a subsequent sampling time in accordance with an estimated observation quantity at the subsequent sampling time of the angular velocity of the variable inertia moment mechanism to set the determined transformation parameter to said state quantity transformation unit.

14. A non-linear characteristic reproducing apparatus according to claim 13, wherein said variable inertia moment mechanism as an object of a characteristic reproduction has a translational member translating in a radius direction in accordance with a centrifugal force, and

said non-linear characteristic reproducing unit comprises: a rotational translation transformation unit for determining a centrifugal force applied to the translational member in accordance with an estimated observation quantity at a subsequent sampling time of the angular velocity of the variable inertia moment mechanism; and a translational motion reproducing unit for reproducing a translational motion of the translational member by the centrifugal force determined by said rotational translation transformation unit, and said non-linear characteristic reproducing unit determines a transformation parameter according to the translational motion of the translational member reproduced by said translational motion reproducing



unit to set the determined transformation parameter to said state quantity transformation unit.

15. A non-linear characteristic reproducing  
5 apparatus comprising a linear model unit for reproducing characteristics of a linear system, and a non-linear model unit for determining, upon receipt of an estimated observation quantity at a subsequent sampling time of at least one state quantity of a first state quantity and a  
10 second state quantity, which are in a relation of mutually non-linear transformation, or a state quantity derived from said one state quantity, from said linear model unit, a transformation parameter used for a linear transformation at the subsequent sampling time between the first state  
15 quantity and the second state quantity,

wherein an operation of determining the transformation parameter at the subsequent sampling time in said non-linear model unit and a linear operation including a linear transformation between the first state quantity  
20 and the second state quantity using the transformation parameter at the subsequent sampling time determined in said non-linear model unit, in said linear model unit are alternatively repeated.

25 16. A non-linear characteristic reproducing apparatus according to claim 15, wherein said non-linear model unit has a plurality of non-linear transformation

units for determining, upon receipt of an estimated observation quantity at a subsequent sampling time of at least one state quantity of a first state quantity and a second state quantity, which are in a relation of mutually non-linear transformation and at least one of which is different in type, or a state quantity derived from said one state quantity, a transformation parameter used for a linear transformation at the subsequent sampling time between the first state quantity and the second state quantity.

17. A non-linear characteristic reproducing apparatus according to claim 15, wherein said non-linear characteristic reproducing apparatus is an apparatus for reproducing characteristics of Geneva mechanism,

said linear model unit performs linear transformations including a linear transformation of angular velocity-to-angular velocity between master section and slave section of the Geneva mechanism, and a linear transformation of torque-to-torque between master section and slave section of the Geneva mechanism, and

said non-linear model unit has a non-linear transformation unit for determining a transformation parameter including information as to whether master section and slave section of the Geneva mechanism are connected to one another at the subsequent sampling time, said information being used for both the linear

transformation of angular velocity-to-angular velocity  
between master section and slave section of the Geneva  
mechanism and the linear transformation of torque-to-torque  
between master section and slave section of the Geneva  
5 mechanism, at a subsequent sampling time of an angle of the  
master section of the Geneva mechanism, in accordance with  
an estimated observation quantity at the subsequent  
sampling time.

10 18. A non-linear characteristic reproducing  
apparatus according to claim 15, wherein said non-linear  
characteristic reproducing apparatus is an apparatus for  
reproducing characteristics of a liquid residue warning  
lamp in which a lamp and a thermistor are connected in  
15 series,

said linear model unit performs linear  
transformations including a transformation between a  
voltage applied to the lamp and a current conducting  
through the lamp and a transformation between a voltage  
20 applied to the thermistor and a current conducting through  
the thermistor, and

said non-linear model unit has a first non-linear  
transformation unit for determining a resistance of the  
thermistor at a subsequent sampling time of a consumed  
25 power of the thermistor in accordance with an estimated  
observation quantity at the subsequent sampling time.

19. A non-linear characteristic reproducing apparatus comprising:

a logical decision unit for receiving one or more variables, and determining a logical value at a subsequent sampling time, selected among from a plurality of discrete values in accordance with the received one or more variables; and

a state quantity selecting unit for receiving a predetermined input state quantity and outputting at the subsequent sampling time an output state quantity in which a relation between the input state quantity and the output state quantity is changed over to a relation according to the logical value at the subsequent sampling time determined by said logical decision unit.

20. A non-linear characteristic reproducing apparatus according to claim 19, wherein said state quantity selecting unit outputs at the subsequent sampling time an output state quantity in which a relation between the input state quantity and the output state quantity is changed over to a connection relation according to the logical value at the subsequent sampling time determined by said logical decision unit.

21. A non-linear characteristic reproducing apparatus according to claim 19, wherein said state quantity selecting unit integrates the input state quantity

and outputs as an output state quantity, and in a case where the logical value at the subsequent sampling time determined by said logical decision unit is a predetermined logical value, said state quantity selecting unit outputs  
5 an output state quantity which is changed over to an initial value at the subsequent sampling time.

22. A non-linear characteristic reproducing apparatus according to claim 19, wherein said logical  
10 decision unit determines a logical value at a subsequent sampling time, selected among from a plurality of discrete values in accordance with an estimated observation quantity at the subsequent sampling time of a plurality of input state quantities, and

15 said state quantity selecting unit receives the plurality of input state quantities and outputs at the subsequent sampling time in form of an output state quantity an input state quantity selected in accordance with the logical value at the subsequent sampling time  
20 determined by said logical decision unit.

23. A non-linear characteristic reproducing apparatus according to claim 19, wherein said non-linear characteristic reproducing apparatus is an apparatus for  
25 reproducing characteristics of a mechanism including two members having a relative movement possible state and a relative movement impossible state,

said logical decision unit determines a logical value representing whether said two members are in the relative movement possible state or the relative movement impossible state in accordance with an estimated observation quantity at a subsequent sampling time of a relative position of said two members or a state quantity derived from the relative position of said two members, and

said state quantity selecting unit changes over a relation between a relative moving velocity and a distribution of force of said two members.

24. A non-linear characteristic reproducing apparatus according to claim 19, wherein said non-linear characteristic reproducing apparatus is an apparatus for reproducing characteristics of a clutch mechanism including two members having a relatively slid sliding state and a mutually connected connecting state,

said logical decision unit determines a logical value representing whether said two members are in the sliding state or the connecting state in accordance with an estimated observation quantity at a subsequent sampling time of a relative angular velocity of said two members, and

said state quantity selecting unit changes over a relation between a relative angular velocity and a distribution of torque of said two members.

25. A non-linear characteristic reproducing apparatus according to claim 19, wherein said non-linear characteristic reproducing apparatus is an apparatus for reproducing characteristics of a brake mechanism for applying a braking energy to a driving shaft,

said logical decision unit determines a logical value representing whether the driving shaft is in a rotating state or a stationary state in accordance with an estimated observation quantity at a subsequent sampling time of a torque which a brake receives from the driving shaft, and

said state quantity selecting unit changes over a braking torque to be applied to the driving shaft.

26. A non-linear characteristic reproducing apparatus according to claim 19, wherein said non-linear characteristic reproducing apparatus is an apparatus for reproducing characteristics of an automatic-reset mechanism in which a spring is effected on a movable member, and when application of an external force to the movable member is removed, the movable member is automatically reset to an initial state by an effect of the spring, said automatic-reset mechanism having a stopper to limit a movable range of the movable member,

said logical decision unit determines a logical value representing whether the movable member interferes with the stopper in accordance with an estimated

observation quantity at a subsequent sampling time of a moving position of the movable member, and

said state quantity selecting unit changes over a relation between velocity or angular velocity of the movable member and force or torque to be applied to the movable member.

27. A non-linear characteristic reproducing apparatus wherein upon receipt of a predetermined first state quantity, a second state quantity changed over to a non-linearity according as the received first state quantity is in a predetermined state is generated, said non-linear characteristic reproducing apparatus comprising:

a state variation estimation unit for predicting a state quantity variation width during a period from a present sampling time to a subsequent sampling time of the first state quantity;

a state deviation detection unit for determining a deviation between a value at the present sampling time of the first state quantity and a decision value for deciding whether the first state quantity is in a predetermined state;

a stable state decision unit for determining a logical value to be selected from among a plurality of discrete values, predicting a non-linear variation at a subsequent sampling time in accordance with a comparison of the state quantity variation width predicted by said state



variation estimation unit with the deviation determined in  
said state deviation detection unit; and

5 a state quantity selecting unit for outputting the  
second state quantity changed over in accordance with the  
logical value determined in said stable state decision unit.

28. A non-linear characteristic reproducing  
apparatus according to claim 27, wherein said state  
deviation detection unit determines a deviation between a  
10 value at the present sampling time of the first state  
quantity and a decision value for deciding whether the  
first state quantity is in a predetermined state, said  
decision value being varied in accordance with positive or  
negative of the state quantity variation width predicted in  
15 said state variation estimation unit.

29. A non-linear characteristic reproducing  
apparatus comprising:

20 a linear model unit for reproducing  
characteristics of a linear system, including a state  
quantity transformation unit for linear-transforming a  
first state quantity to a second state quantity in  
accordance with a transformation parameter set up; and

25 a non-linear model unit for generating, upon  
receipt of an estimated observation quantity at a  
subsequent sampling time of a predetermined first  
observation state quantity from said linear model unit, the

transformation parameter in accordance with the received  
estimated observation quantity and setting the generated  
transformation parameter on said state quantity  
transformation unit,

5            wherein said non-linear model unit comprises:

          a slow change reproducing unit for receiving from  
said linear model an observation quantity or an estimated  
observation value of a predetermined second observation  
state quantity identical to or different from the first  
10    observation state quantity, to generate a slow change state  
quantity reflecting characteristic of a first non-linear  
system offering a relatively slow behavior change in  
accordance with the observation quantity or the estimated  
observation value of the second observation state quantity;  
15    and

          a characteristic generating unit for generating a  
transformation parameter reflecting characteristic of a  
second non-linear system offering a relatively rapid  
behavior change in accordance with the estimated  
20    observation value at a subsequent sampling time of the  
first observation state quantity derived from said linear  
model unit and the slow change state quantity generated in  
said slow change reproducing unit and setting up the  
generated transformation parameter on said state quantity  
25    transformation unit.

30. A non-linear characteristic reproducing

apparatus according to claim 29, wherein said slow change reproducing unit comprises:

5 a stationary value setting up unit for determining a stationary value, after passage of an infinite time, of the slow change state quantity assuming that a state of said linear model unit is maintained, in accordance with the observation quantity or the estimated observation value of the second observation state quantity; and

10 a normalization response unit for generating the slow change state quantity reflecting characteristic of the first non-linear system, which is to be transferred to said characteristic generating unit, in accordance with a stationary value of the slow change state quantity determined in said stationary value setting up unit, and a  
15 known normalized time change characteristic of the slow change state quantity in the first non-linear system.

31. A non-linear characteristic reproducing apparatus according to claim 30, wherein said non-linear  
20 characteristic reproducing apparatus is an apparatus for reproducing characteristics of a system having an element which is varied in a resistance value in accordance with a temperature variation,

25 said state quantity transformation unit sets up a transformation parameter representative of the resistance value and performs a transformation between a voltage applied to the element having the resistance value and a

current conducting through the element,

said stationary value setting up unit determines a stationary value, after passage of an infinite time, of a temperature of the element assuming that an energy to be consumed in the element is maintained, in accordance with the estimated observation quantity at a subsequent sampling time of the energy to be consumed in the element,

said normalization response unit determines a temperature of the element in accordance with a stationary value of the temperature of the element determined in said stationary value setting up unit, and a known normalized step response curve representative of a time variation of the temperature of the element to a variation of an energy to be consumed in the element, and

said characteristic generating unit generates a transformation parameter representative of the resistance value of the element in accordance with the temperature determined in said normalization response unit and sets up the generated transformation parameter on said state quantity transformation unit.

32. A non-linear characteristic reproducing apparatus according to claim 31, wherein said normalization response unit determines a temperature of the element in accordance with an observation quantity of an ambient temperature.

33. A non-linear characteristic reproducing  
program storage medium storing a non-linear characteristic  
reproducing program which causes a computer to operate as a  
non-linear characteristic reproducing apparatus wherein  
5 upon receipt of a predetermined first state quantity, a  
non-linear transformation processing is applied to the  
entered first state quantity so that a second state  
quantity is generated and outputted,

wherein said non-linear characteristic reproducing  
10 program storage medium stores a non-linear characteristic  
reproducing program comprising:

a state quantity transformation unit for linear-  
transforming the first state quantity to the second state  
quantity every sampling time in accordance with a  
15 transformation parameter set up; and

a non-linear characteristic reproducing unit for  
determining a transformation parameter for transformation  
at a subsequent sampling time in accordance with an  
estimated observation quantity at the subsequent sampling  
20 time of at least one state quantity of the first state  
quantity and the second state quantity or a state quantity  
derived from said one state quantity to set the determined  
transformation parameter to said state quantity  
transformation unit.

34. A non-linear characteristic reproducing  
program storage medium storing a non-linear characteristic

reproducing program which causes a computer to operate as a non-linear characteristic reproducing apparatus for reproducing characteristics of a system including a non-linear system,

5            wherein said non-linear characteristic reproducing program storage medium stores a non-linear characteristic reproducing program comprising:

             a linear model unit for reproducing  
characteristics of a linear system, and a non-linear model  
10    unit for determining, upon receipt of an estimated  
observation quantity at a subsequent sampling time of at  
least one state quantity of a first state quantity and a  
second state quantity, which are in a relation of mutually  
non-linear transformation, or a state quantity derived from  
15    said one state quantity, from said linear model unit, a  
transformation parameter used for a linear transformation  
at the subsequent sampling time between the first state  
quantity and the second state quantity,

             wherein an operation of determining the  
20    transformation parameter at the subsequent sampling time in  
said non-linear model unit and a linear operation including  
a linear transformation between the first state quantity  
and the second state quantity using the transformation  
parameter at the subsequent sampling time determined in  
25    said non-linear model unit, in said linear model unit are  
alternatively repeated.

35. A non-linear characteristic reproducing  
program storage medium storing a non-linear characteristic  
reproducing program which causes a computer to operate as a  
non-linear characteristic reproducing apparatus for  
5 reproducing characteristics of a system including a non-  
linear system,

wherein said non-linear characteristic reproducing  
program storage medium stores a non-linear characteristic  
reproducing program comprising:

10 a logical decision unit for receiving one or more  
variables, and determining a logical value at a subsequent  
sampling time, selected among from a plurality of discrete  
values in accordance with the received one or more  
variables; and

15 a state quantity selecting unit for receiving a  
predetermined input state quantity and outputting at the  
subsequent sampling time an output state quantity in which  
a relation between the input state quantity and the output  
state quantity is changed over to a relation according to  
20 the logical value at the subsequent sampling time  
determined by said logical decision unit.

36. A non-linear characteristic reproducing  
program storage medium storing a non-linear characteristic  
25 reproducing program which causes a computer to operate as a  
non-linear characteristic reproducing apparatus wherein  
upon receipt of a predetermined first state quantity, a

second state quantity changed over to a non-linearity according as the received first state quantity is in a predetermined state is generated,

wherein said non-linear characteristic reproducing  
5 program storage medium stores a non-linear characteristic reproducing program comprising:

a state variation estimation unit for predicting a state quantity variation width during a period from a present sampling time to a subsequent sampling time of the  
10 first state quantity;

a state deviation detection unit for determining a deviation between a value at the present sampling time of the first state quantity and a decision value for deciding whether the first state quantity is in a predetermined  
15 state;

a stable state decision unit for determining a logical value to be selected from among a plurality of discrete values, predicting a non-linear variation at a subsequent sampling time in accordance with a comparison of  
20 the state quantity variation width predicted by said state variation estimation unit with the deviation determined in said state deviation detection unit; and

a state quantity selecting unit for outputting the second state quantity changed over in accordance with the  
25 logical value determined in said stable state decision unit.

37. A non-linear characteristic reproducing



program storage medium storing a non-linear characteristic reproducing program which causes a computer to operate as a non-linear characteristic reproducing apparatus for reproducing characteristics of a system including a non-linear system,

wherein said non-linear characteristic reproducing program storage medium stores a non-linear characteristic reproducing program comprising:

a linear model unit for reproducing characteristics of a linear system, including a state quantity transformation unit for linear-transforming a first state quantity to a second state quantity in accordance with a transformation parameter set up; and

a non-linear model unit for generating, upon receipt of an estimated observation quantity at a subsequent sampling time of a predetermined first observation state quantity from said linear model unit, the transformation parameter in accordance with the received estimated observation quantity and setting the generated transformation parameter on said state quantity transformation unit,

wherein said non-linear model unit comprises:

a slow change reproducing unit for receiving from said linear model an observation quantity or an estimated observation value of a predetermined second observation state quantity identical to or different from the first observation state quantity, to generate a slow change state

quantity reflecting characteristic of a first non-linear system offering a relatively slow behavior change in accordance with the observation quantity or the estimated observation value of the second observation state quantity;

5 and

a characteristic generating unit for generating a transformation parameter reflecting characteristic of a second non-linear system offering a relatively rapid behavior change in accordance with the estimated observation value at a subsequent sampling time of the first observation state quantity derived from said linear model unit and the slow change state quantity generated in said slow change reproducing unit and setting up the generated transformation parameter on said state quantity transformation unit.

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